Enhanced Spectral Efficiency for 5G Massive MIMO System

K. P. Rajesh M. Mary Synthuja Jain Preetha

Abstract*: In this paper a new SE expression is derived which is analyzed with different linear precoding schemes. Also the effects of Pilot Reuse factor and inter cell interference is included in the simulation. The results concluded that the new scheme performs better than the existing schemes for more number of antennas. Since the proposed method shows better performance for higher number of antennas, this system can be adaptively used for Massive MIMO 5Gsystems whose basic feature is large number of transmitting antennas. The increase in SE will improve the throughput of the system which directly serves the eMBB use case of the 5G service. Massive MIMO is the emerging technology in cellular system for higher data rate communication. It employs large number of transmitting antenna at the base station which is made possible by the antenna array which can be electronically steerable and effectively used for beam forming. Spectral efficiency is the key parameter to be improved in increasing throughput. Here a new expression for Spectral efficiency is formulated and analyzed with few linear precoding and combining methods. The effects of pilot reuse factor and intercell interference is taken into account. The simulated results give a better performance improvement when the number of antennas is large which the expected outcome of this work is. This method can improve the throughput of the system and hence can be used for 5G communication

***Index Terms*: Massive MIMO, Spectral Efficiency, Pilot reuse factor.**

I. INTRODUCTION

Communication Generations show a steady growth in its technological aspects. The latest version is the 5G wireless network which is the advanced version of 4G. 5G is not a mere development or expansion of 4G. 5G incorporates several new techniques. The 5G standard is developed in the aspect considering new changes in the deployment architecture also.ITU has developed there major use cases for 5 G network[1].They are i)eMBB (Enhanced Mobile Broad band) ii)uLLC (Ultra Reliable Low Latency Communication), iii) mMTC (Massive Machine Type Communication). ForeMBB based applications, Throughput is the key parameter. eMBB relay on several techniques to improve throughput so as to achieve higher data rate which supports high speed communication for a large number of users [2]. 5G aims in increasing the data rate to 1000 times from the present standards. This is theoretically achieved by increasing each parameter in the right hand side of equation (1) by a factor of 10, so that the Throughput in left hand side increases by 1000 times. But in practice this is not easily achievable. Bandwidth cannot be increased as the spectrum is one of the most costly things in universe. Cell density is the number of base station (BS) within the specified area called the cell. Increasing the number of base stations is also not feasible as it is expensive to deploy new BSs. Hence the better and economic approach is to improve the spectral efficiency (SE) to improve Throughput.

There are several methods proposed to improve spectral efficiency [3-4]. Massive MIMO is one of the best approach to improve SE and also it supports with the hardware system having large number of antennas as in a 5G system. Hence massive MIMO approach will be a better solution for improving SE for 5G systems. Optimizing the number of antenna is reported in [2-4].The cellular system has several base Station which operates in a coherent fashion [5].It provides better array gain and spatial resolution that allows maintaining robustness to inter cell interference [6]. The aggressive multiplexing in massive MIMO has contributed for the betterment of overall efficiency [4-7].

Massive MIMO resource allocation [8] has given guidelines to be followed for the system. The impact of pathloss and spatial correlation with respect to UE interference is given in [8-10].In this paper a new SE expression is derived and it is analyzed with respect to several other parameters considering the random spread of UE along the cells with different interference levels. Here a multi cell system is considered and the problem statement is formulated in such a way that how higher throughput is achieved through higher SE for multi users within the cell. In this work we have proposed a new expression for SE and analyze its performance with respect to different system parameters like coherence block length, Base station antennas etc. Also precoding schemes like Maximum Ratio Combining (MR), Zero Forcing (ZF), Full Pilot Zero Forcing (P-ZF) schemes are used for comparison. This paper is organized as follows. Section II defines the Uplink and Downlink MIMO System Models with random user location. Section III analyzes new SE expression with those of MR, ZF, P-ZF schemes.

II. SYMBOL MODEL

Let us consider a cellular network in which data is transmitted with universal time and frequency reuse. Let us name the cell with an index from the set of variables in the set L. Also the base station with in the cell is equipped with an array of M Antenna which is more than the number of active users K with single antenna devices.

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Let maximum number of users be K_{max} .Since Massive MIMO topology is assumed for the study always choose M>K. The active user numbers may vary from time to time. Each cell is assigned a number l Є L. The geographical position Zlk Є R^2 is the location of user equipment (UE) k in the cell l is a random variable with cell specific distribution. This can be used to study the random behavior of UE k with the cell l.

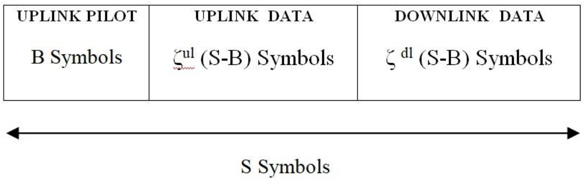

Fig 1. Frame structure of the data transmission

The network transmission is divided into frames of S symbols. Let B be the number of pilot symbols. The rest of the frame bits is shared between uplink and downlink depending on the uplink and downlink fraction ζ^{ul} and ζ^{dl} respectively. These parameters separate the rest of the bits into positive integers with the constraint $\zeta^{ul}+\zeta^{dl}=1$.

A. Uplink

Let us consider that the UE k is active in the cell l. The uplink signal is related to the transmit power given by P_{lk}>=0. $hjlk$ is the channel response between BSj and UE k in the cell l.xlk is the transmitted signal by the UE. Then the received signal is modeled as

$$yj = \sum_{l\in L}\sum_{k=1}^{K}\sqrt{P_{lk}}\, hjlk\ xlk\ + nj \qquad (1)$$

Most previous work on Massive MIMO considers fixed UL power. Here in this work we assume a power control policy [11] which inverts the channel attenuation and avoids near far blockage.

B. Downlink

MIMO TDD is capable of channel reciprocity. Here the uplink (UL) parameters can be used for downlink (DL) expression also. Hence the DL signal Zjk at UE k in the cell in a frame is modeled as

$$z_{jk} = \sum_{l\in L}\sum_{m=1}^{K} h_{jlk}^{T}\ \ w_{lm}\, s_{lm} + \ n_{jk} \qquad (2)$$

Where w_{lm} is the precoding vector. All parameters used in the downlink are the similar estimate of uplink. The UL/DL model described above assumes perfect synchronization across all cells. For Multicell Environment, the interference from cells close to the neighboring cells is synchronously received and can be suppressed. At the same time the signal from far away cell is asynchronously received and cannot be suppressed, but power of signal is too low. This low power signal will not cause a serious interference.

C. Achievable UL & DL Spectral Efficiency

The ergodic achievable SE for a random UE over a Rayleigh fading channel with random UE location which interfere with other UE is given as

$$\zeta^{(ul)}\left(1-\frac{B}{S}\right) E_{\{z\}}\left\{log_2(SINR_{jk}^{(ul)})\right\} \qquad (3)$$

Where SINR –Signal to interference ratio.

E {.} is calculated with respect to UE position. Let us consider more than one cell use the same pilot. In this case Lj(β)Є L is the subset of cell which use the same pilot as cell j Now the expression of achievable SE is

$$SE_j^{(ul)} = K.\zeta^{(ul)}\left(1-\frac{B}{S}\right)\log_2\left(1+\frac{1}{I_j^{scheme}}\right) \qquad (4)$$

The interference term of equation (5) has two terms. The first term explains about the pilot contamination since it uses pilot reuse factor. The second term explains inter user interference. In the proposed scheme P-Z Fn which is modified version of PZF, the first term of SE maintains array gain in the way between MR and ZF Where as the inter cell interference is reduced similar to PZF term.

D. Achievable DL Spectral Efficiency

Since the channel estimates for UL can be used for DL, we get a similar expression for DL. DL Spectral Efficiency for a cell j is given as

$$\zeta^{(dl)}\left(1-\frac{B}{S}\right) E_{\{z\}}\left\{log_2(SINR_{jk}^{(dl)})\right\} \qquad (5)$$

Optimize SE taking Different Frequency Reuse factor and Interference Levels into account. Frequency reuse factor is the universal concept of cellular communication. Cellular concept has evolved before decades [12]. The symmetric cells in cellular communication are assumed to be regular polygons, usually hexagon [13]. The different patterns of hexagonal network with different frequency reuse factor are shown in the figure 2.

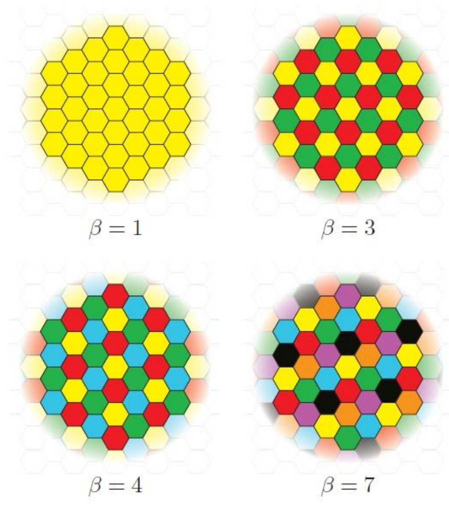

Fig. 2. Hexagonal network with different pilot reuse factors

Since the objective of this work is improving spectral efficiency for massive MIMO, we consider pilot books of size B= βK which enables non universal pilot reuse [8].This suppresses the pilot contamination effect of neighboring cells. There are certain conditions for choosing pilot reuse factor β. The previous work related to hexagonal networks [12-13] limits these pilot reuse factor βЄ {1, 3, 4, 7, 9……}.

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For simulating SE we consider a random cell chosen from the figure 2 taking all major interference into account. The UE can be anywhere in the cell from a certain distance away from the serving BS. Same linear preceding and combining schemes are used. The simulation is run for all M to obtain SE and different pilot reuse factors are also taken into account.
In addition to this, three cases of propagation environment with different inter cell interference is also considered for simulation. For Best case, all UE in the other cell are away from the serving base station BS of the cell. Worst case is one with all UEs of other cells are close to the serving BS of the simulated cell. These two approaches are too optimistic and pessimistic respectively, which is not common as real time environment. Taking real time parameters like UE mobility, Switching, Scheduling the average case is most applicable in practice.

III. SIMULATION RESULTS

We first simulate the system with a Best case interference environment. The simulation is run as the function of M with respect to Spectral efficiency and Number of scheduled users. The simulation is run for the proposed method PZFn and other linear methods in the literature say MR, ZF and PZF. The simulated result is shown in the figure 3.

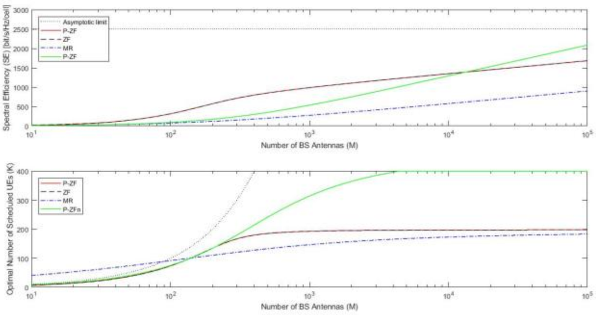

Fig 3. Best Case Inter cell Interference Simulation as function of M

Next we simulate the worst case interference, where we assume all UEs of other cells are close to BS current cell. As in best case the simulation is run as the function of M with respect to Spectral efficiency and Number of scheduled users. The simulated result is shown in figure 4.

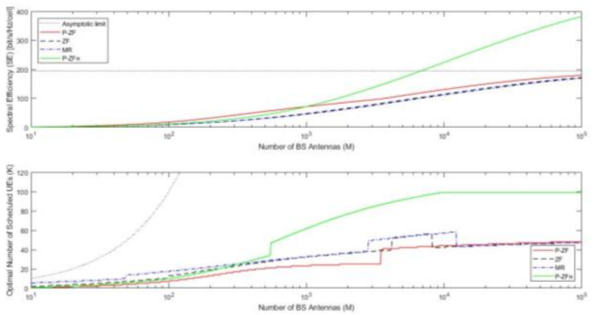

Fig. 4.Worst Case Inter cell Interference Simulation as function of M

The Average case Interference Simulation is done which is mostly use for the practical scenario evaluation. The simulation result is shown in figure 5.

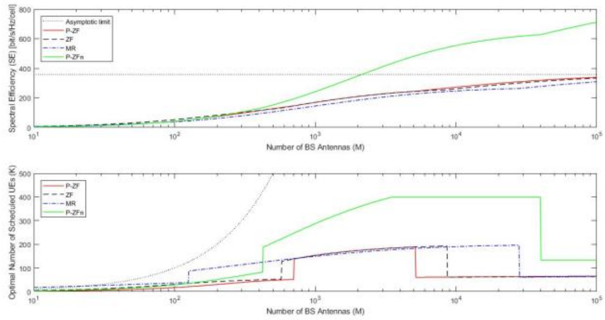

Fig. 5. Average Case Inter cell Interference Simulation as function of M

From the above three cases it is found that SE of the proposed P-ZFn Scheme shows an average performance for lower number of antennas. Even it shows a lower performance in figure 3 for antenna number less than 1000. But in all cases when the antenna number is more than 1000 the proposed method shows a steady increase in its performance. Similar approach is observed for the number of scheduled users in all the three cases. Hence the proposed method PZFn provided higher SE which in turn supports high throughput. Also the proposed methods displays better for higher number of antennas; it can be used in 5G massive MIMO which by default uses large antenna array systems.

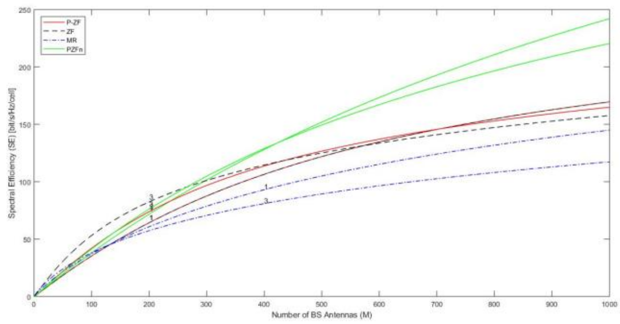

Fig. 6. The system performance for different Frequency Reuse factors (β=1 and β=3)

The impact of pilot reuse factor is analyzed using the formula 5 and the result is shown in Fig.6. This shows simulated result for two different frequency reuse factors. In general the both the graphs corresponding to the different frequency reuse factors give the same values. The performances of different schemes are also clear. The proposed P-ZFn method shows better performance compared to other schemes.

IV. CONCLUSIONS

In this paper a new SE expression is derived which is analyzed with different linear precoding schemes. Also the effects of Pilot Reuse factor and inter cell interference is included in the simulation. The results concluded that the new scheme performs better than the existing schemes for more number of antennas.

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Since the proposed method shows better performance for higher number of antennas, this system can be adaptively used for Massive MIMO 5G systems whose basic feature is large number of transmitting antennas. The increase in SE will improve the throughput of the system which directly serves the eMBB use case of the 5G service.

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